Domestic heating and hot water

– choice of fuel and system type

Better heating and hot water systems will:

- lower running costs
- reduce CO_2 emissions
- improve comfort
- help to provide affordable warmth
- increase customer satisfaction

(See Good Practice Guide 284 for central heating systems with gas and oil-fired boilers)

BEST PRACTICE PROGRAMME

HOUSING ENERGY EFFICIENCY

BEST PRACTICE PROGRAMME

GOOD PRACTICE GUIDE 301

CONTENTS

For wet central heating systems see Good Practice Guide 284 ‘Domestic central heating and hot water: systems with gas and oil-fired boilers – guidance for installers and specifiers’.

Further reference should always be made to manufacturers’ instructions, Building Regulations, standards and codes of practice.

The following organisations were consulted during preparation and have expressed their support for this Guide: Advantica Technologies Ltd; Institution of Domestic Heating and Environmental Engineers; Solar Trade Association; Underfloor Heating Manufacturers Association; Society for British Gas Industries; Heating Equipment Testing and Approval Scheme Ltd and Solid Fuel Association.

1 INTRODUCTION

The aim of this Guide is to assist installers, specifiers and purchasers of domestic heating and hot water systems by providing guidance on selecting heating and hot water systems to:

- improve energy efficiency
- reduce running costs
- reduce emissions of carbon dioxide (CO_2).

The Guide covers ducted warm air, solid fuel and electric heating and hot water systems, and individual appliances heating a single room. It gives only brief details of gas and oil-fired 'wet' ('hydronic') central heating systems, ie those in which water is circulated to heat emitters from a boiler, as they are covered in detail in Good Practice Guide 284[1].

The overall energy efficiency of domestic heating and hot water systems has a major impact on both the running costs and the associated CO_2 emissions. The efficiency of most heating and hot water products has increased in recent years but care must still be taken to choose the most appropriate system if it is to perform its function both efficiently and effectively.

This Guide is published as part of the Government's Energy Efficiency Best Practice programme, the building-related aspects of which are managed by BRECSU. It brings together information on most of the different heating and hot water product types that are now available, the types of systems to which they can be fitted, and key points to consider when choosing them for a particular application.

ENERGY USE IN THE HOME

Heating and hot water systems consume far more energy than other household appliances and represent the largest proportion of CO_2 emissions from domestic energy consumption. A typical household with central heating consumes a total of about 23 000 kWh of energy each year, of which 84% is for heating and hot water. Therefore, it is particularly important to ensure that the provision of heating and hot water in the home is achieved in the most efficient manner possible.

ENERGY AND THE ENVIRONMENT

With the exception of renewable energy sources and nuclear power, most energy is generated by combustion, with CO_2 as an inevitable by-product, be this in the boiler, from the cooker or at the power station. CO_2 is an important greenhouse gas and is widely accepted to have a significant impact on climate change. Using efficient heating and hot water systems significantly reduces emissions of CO_2, which in turn lessens the impact on the environment.

HOME ENERGY RATINGS

An energy rating aims to inform householders of the overall energy efficiency of a home in a way that is simple to understand and allows easy comparison with similar properties. A number of different methods have been launched, mostly based on the domestic energy model known as BREDEM[2]. The Standard Assessment Procedure (SAP) is the Government's recommended method for home energy rating[3] (see the box overleaf).

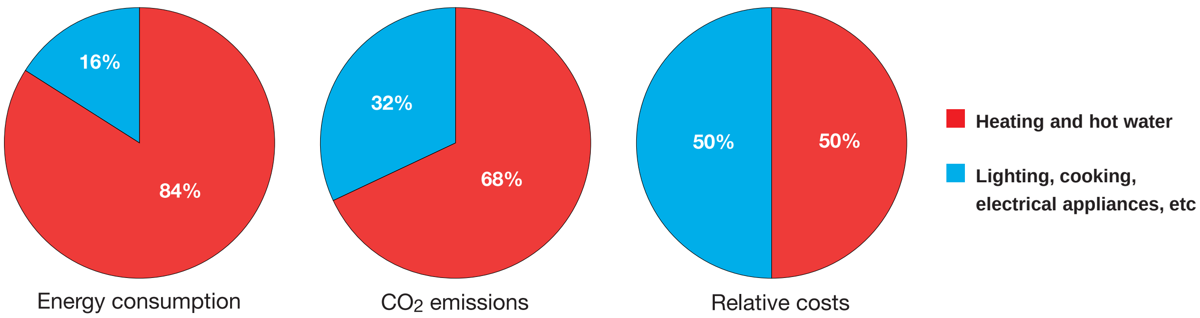


Figure 1 Energy use in the UK housing stock

INTRODUCTION

WHAT IS SAP?

SAP is the Government's Standard Assessment Procedure for producing an energy rating for a dwelling, based on the calculated annual energy cost for space and water heating. The calculation assumes standard occupancy and heating patterns, and takes into account the thermal insulation of the building fabric; the efficiency and control of the heating system(s); ventilation characteristics; solar gain and the price of fuels used.

The SAP rating is normalised for floor area so that the size of the dwelling does not strongly affect the result, which is expressed on a scale of 1 to 120 – the higher the number the better the standard. A carbon index is also produced by SAP 2001 on a scale of 0.0 – 10.0 (the higher the number the lower the carbon emitted). This can be used to demonstrate compliance with Building Regulations for the conservation of fuel and power.

The Building Regulations[4] require all new homes to be SAP rated. There is no minimum standard but some housing providers specify a target SAP value as a measure of efficiency. Clearly, the choice of heating and hot water systems and the fuels used will markedly affect the SAP rating of a house.

The method of calculation for SAP is set out in the form of a worksheet, accompanied by a series of tables, or an approved computer program.

2 FUEL CHOICE

DOMESTIC ENERGY CONSUMPTION

About 1860 TWh of energy is delivered to final users in the UK, of which 540 TWh is consumed by the domestic sector. There are presently 24.7 million households in the UK and it is estimated that 91% have central heating installed. The split, by fuel, is shown in figure 2.

A typical household with gas central heating consumes about 23 000 kWh of total energy each year, of which 84% is for heating and hot water. However there are many types of other heating systems that represent opportunities for fuel switching, with potentially significant savings of energy and associated CO_2 emissions.

Primary energy is measured as the calorific value of fuels or energy sources at the input to a process for producing and supplying energy. It accounts for energy used in the extraction, transportation, conversion and delivery to the consumer.

Delivered energy is measured by its calorific value as it is delivered to the consumer. For commercial sources of energy, this is essentially the amount metered and paid for by the consumer. Gross calorific value is used in the UK. It is the most generally useful definition and by far the most widely measured and best understood.

Useful energy is the energy required for a specific end-use after conversion at the consumer's premises and net of any losses that may occur during conversion. Useful energy is frequently calculated but rarely measured. It is most meaningful when the energy service produced can itself be calculated in energy units, which is the case for heating. For other uses of energy, such as lighting and many domestic electrical appliances, the 'output' obtained cannot be measured adequately in energy units.

Figure 3 shows how UK energy is lost along the supply chain. Data for primary and delivered energy is taken from the Digest of UK Energy Statistics 2001[5]. The difference between primary and delivered energy for electricity is much larger than for other fuels, including gas, and clearly illustrates the energy losses incurred in electricity generation. Most fuels experience a significant conversion loss as they are converted from delivered energy to final (useful) energy, but although electricity has a higher point-of-use efficiency, this does not compensate for earlier inefficiencies. A comparison of delivered energy to UK homes is illustrated in figure 4.

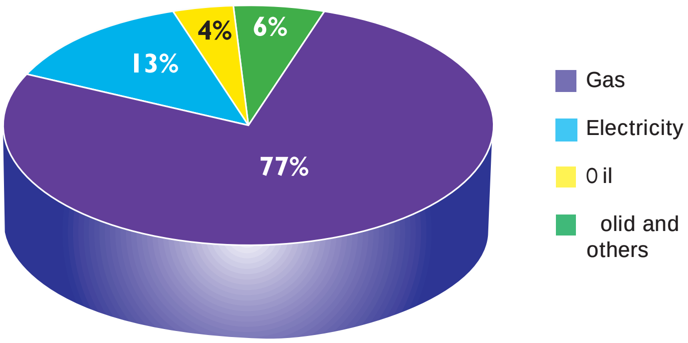


Figure 2 Domestic heating systems by fuel type in the UK (1996)[6]

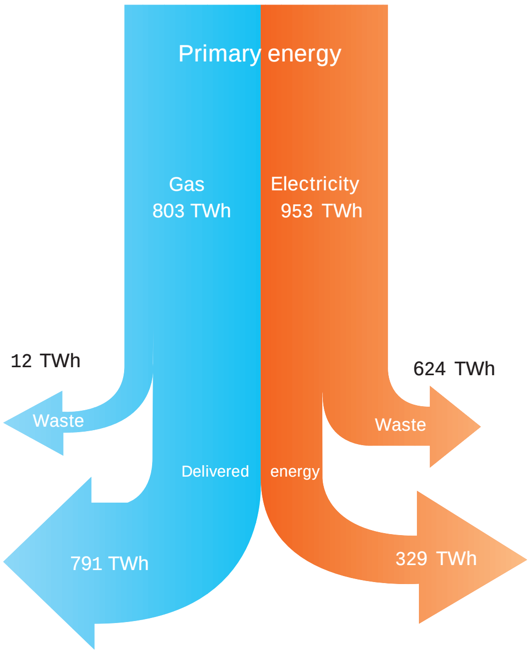


Figure 3 Primary and delivered UK energy flows

FUEL CHOICE

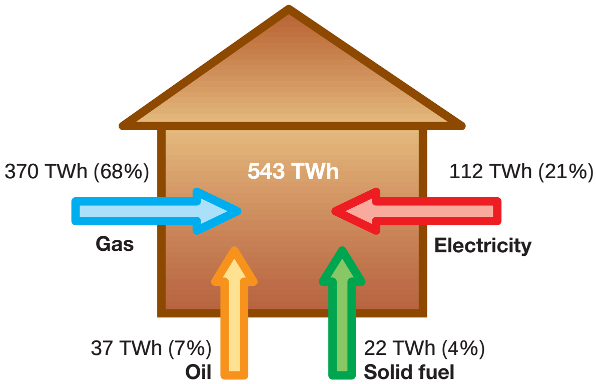


Figure 4 Comparison of delivered energy to UK homes by fuel type (TWh)

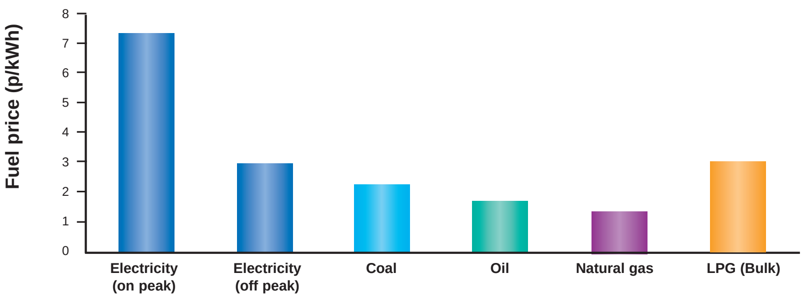


Figure 5 Comparison of fuel prices (2001)

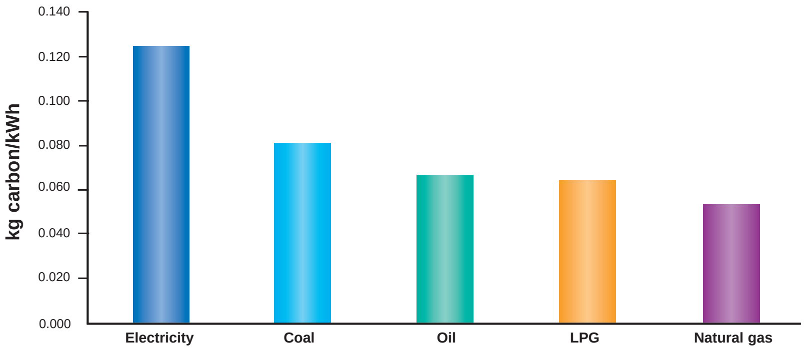


Figure 6 Comparison of CO_2 emissions for different fuels (expressed as kg of carbon per kWh)

EFFICIENCY OF USE

An evaluation of primary energy usage is crucial if the environmental impact assessment of CO_2 emissions is to be given a proper perspective. Great care must be taken when interpreting efficiencies taken from equipment specifications. For example, many electrical products will quote thermal efficiencies of 100%. This is only true for the point of use. It overlooks inefficiencies of electrical generation. For boilers the quoted efficiency may be full-load efficiency measured under specified laboratory operating conditions, which is very different from average installed efficiency in the house. Efficiencies can considerably reduce when the system operates at part load, which is for most of the year. So it is important to use a value that represents the seasonal average operational efficiency. For gas and oil boilers only, this is expressed by the Seasonal Efficiency for Domestic Boilers in the UK (SEDBUK) for use in SAP (see 'Gas and oil boilers' on page 8).

RUNNING COSTS

Table 1 (on page 7) shows typical running costs for central heating and hot water for five types of UK dwellings.

The energy consumption has been estimated using BREDEM-12[2]. This estimates annual domestic energy usage based on house design, insulation levels, local climate and heating system design including efficiency and heating usage.

The running costs use typical SEDBUK efficiency values, though they only apply to gas and oil boilers. Other comparable values have been used for other systems. Fuel costs (including VAT) are shown in figure 5 and have been taken from SAP (2001)[3]. They exclude standing charges, liquefied petroleum gas (LPG) tank rental, maintenance and pump running costs.

FUEL CHOICE

ENERGY STORAGE

Electricity is unique in having to be generated at the moment of use – the flick of a switch imposes an immediate change in demand upon the power stations. Because night-time use is much lower than daytime, the cheaper, off-peak tariffs were introduced to encourage electricity usage at night and keep the generator plant operating at optimal conditions. It is possible to store heat locally to shift electrical demand into off-peak periods and electric storage heating systems were developed to exploit the cheaper tariff. For hot water, a central storage cylinder is often used with a 120 litre cylinder being a common family size.

The electricity companies offer a wide range of tariffs to different users, appropriate to use and typical prices for 2001 are shown in figure 5.

CARBON DIOXIDE EMISSIONS

The CO_2 emissions attributable to each fuel are shown in figure 6, expressed in units of kg of carbon per kWh of primary energy. There is a significant difference according to which fuel is selected. The comparison is also highlighted for five types of UK dwellings in table 2. SAP 2001 will have a carbon index as well. This will calculate the carbon associated with energy use, corrected for floor area and scaled between 0 and 10. Good performance is expressed by a high number and a minimum value may be called for in building specifications.

	Flat	Bungalow	Terraced	Semi-detached	Detached
Energy (kWh)	9256	12 114	12 619	14 292	20 261
Natural gas					
Old boiler (heavy weight)	227	297	309	350	496
New boiler (non-condensing)	166	217	227	257	364
New boiler (condensing)	142	186	193	219	310
Oil (kerosene)					
Old boiler	232	304	317	359	508
New boiler (non-condensing)	184	241	251	284	403
LPG					
Old boiler (heavy weight)	498	652	679	769	1090
New boiler (non-condensing)	365	478	498	564	800
New boiler (condensing)	312	408	424	481	681
Coal					
Old boiler (heavyweight)	335	439	457	518	734
New boiler (enclosed fire and back boiler)	310	405	422	478	678
Electricity					
Storage heaters and hot water (off peak)	278	364	379	430	609
Direct-acting heating and hot water (on peak)	691	904	941	1067	1512

Table 1 Typical annual running costs for central heating and hot water

	Flat	Bungalow	Terraced	Semi-detached	Detached
Natural gas					
Old boiler (heavy weight)	0.9	1.2	1.2	1.4	2.0
New boiler (non-condensing)	0.7	0.9	0.9	1.0	1.4
New boiler (condensing)	0.6	0.7	0.8	0.9	1.2
Oil (kerosene)					
Old boiler	1.0	1.4	1.4	1.6	2.3
New boiler (non-condensing)	0.8	1.1	1.1	1.3	1.8
LPG					
Old boiler (heavy weight)	1.1	1.5	1.6	1.8	2.5
New boiler (non-condensing)	0.8	1.1	1.1	1.3	1.8
New boiler (condensing)	0.7	0.9	1.0	1.1	1.6
Coal					
Old boiler (manual feed – unheated space)	1.4	1.9	2.0	2.2	3.2
New boiler (enclosed fire and back boiler)	1.3	1.7	1.8	2.1	2.9
Electricity					
Storage heaters and hot water (off peak)	1.1	1.4	1.5	1.7	2.4
Direct-acting heating and hot water (on peak)	1.1	1.4	1.5	1.7	2.4

Table 2 Annual CO_2 emissions for typical dwellings (expressed as tonnes of carbon)

3 CENTRAL HEATING SYSTEMS WITH BOILERS

BOILER TYPES

Boilers are defined as follows.

- **Regular.** Provide space heating but require a separate storage vessel with internal heat exchanger (usually a coil of copper tube) for production of domestic hot water (DHW). They may be condensing or non-condensing.
- **Combination (combi).** Provide space heating and DHW directly. They may be condensing or non-condensing, and may include an internal water store to improve hot water performance. A special type of combi boiler is a combined primary storage unit (CPSU), which incorporates a large store of water (usually more than 80 litres). This allows radiators to warm up more quickly.

GAS AND OIL BOILERS

Good Practice Guide 284[1] provides a comprehensive introduction to domestic central heating systems with gas and oil boilers.
In particular it outlines the efficiency gains of modern boilers (especially condensing boilers) and factors to be considered when choosing between stored and instantaneous hot water, so no further details are provided in this Guide.

SOLID FUEL BOILERS

Central heating and DHW can be provided from open fires and roomheaters with backboilers, stoves, or individual boilers. All appliances require a suitable chimney to function properly.

Open fires, roomheaters and stoves are often fitted within a chimney breast to provide a focal point. Cookers and individual boilers are floor-mounted with a flue pipe discharging into a chimney.

Independent boilers are slightly larger than other boilers of a similar duty. There are two main types – batch fed and gravity fed.

Gravity feed boilers are available in a wide range of outputs and sizes. These boilers incorporate a large hopper above the fire box that can hold a full day's fuel supply. They burn small anthracite. The fuel feeds down to the fire as required and combustion is assisted by a built-in thermostatically controlled fan, aiding response to demand. Solid fuel boilers can kindle at low combustion rates but, compared with the electric control of gas and oil boilers, this represents a significant standing loss and slight reduction in overall thermal performance, though the additional background heat helps to prevent condensation. As with all heating systems, good time and temperature control of the boiler will ensure the most efficient operation.

Solid fuel boilers remain reliable and robust but lack the controllability and responsiveness of boilers using other fuels. They also require a fuel bunker and need fuelling and cleaning by the user. Flues require sweeping at least once a year to remove chimney deposits. A wide range of fuel products is available but care is needed with all solid fuel appliances to ensure that an appropriate type and grade is used to ensure optimal performance. This is particularly so in smokeless zones where bituminous coal is prohibited. Smokeless fuel is available as manufactured or natural products. Advice on the recommended fuel for a particular boiler should be taken from the manufacturer or HETAS (Heating Equipment Testing and Approval Scheme) guide. HETAS is an independent organisation that undertakes approved testing of solid fuel appliances and services on behalf of the industry and Government. All solid fuels emit relatively high carbon emissions, as shown in table 2 on page 7.

ELECTRIC BOILERS

Electricity is considerably more expensive than alternative fuels (see figure 5 on page 6) and electrically heated wet systems have to use a storage strategy to make economic sense. In its simplest form this comprises a large water tank, beneath the floor perhaps, which is heated overnight using direct-acting immersion heaters running at the cheap tariff. The hot water would then be circulated through the system during the day. The size of the tank is crucial in determining how much heat for use through the day can be stored during the cheap night-time period. To meet the full requirement for a typical house on a cold winter day the store would need to be about 3000 litres and be very well insulated.

CENTRAL HEATING SYSTEMS WITH BOILERS

An alternative is to use a storage boiler that stores the night-time energy in special bricks, rather like a traditional electric storage heater. The heat is subsequently released to the water and circulated to the radiators.

An electric 'combination' boiler is available, although unlike gas and oil combi boilers it does not supply instant hot water. The boiler provides stored DHW and heats radiators. The boiler needs no flue so it can be sited anywhere in the property. The boiler comprises an insulated storage vessel that is heated overnight by immersion heaters using cheap-rate electricity. The primary storage is heated to high temperature (about 90ºC) and blended in a compensated system to provide the right amount of heat to the radiators. A secondary coil is used to heat incoming mains cold water to the required temperature for stored hot water. The boilers can provide peak heating at more than 15 kW or 18 kW respectively but are designed for continuous heat outputs of 9 kW or 12 kW. Running costs and CO_2 emissions will be higher than for alternative fuels.

SEASONAL EFFICIENCY OF DOMESTIC BOILERS IN THE UK (SEDBUK)

SEDBUK is the average annual boiler efficiency achieved in typical domestic conditions. It can be applied to most gas and oil domestic boilers and provides a basis for fair comparison of different models.

There is now a boiler efficiency database showing the (SEDBUK) efficiency of most gas and oil domestic boilers sold in the UK. It can be seen on the web at **www.boilers.org.uk**. Both current and obsolete boilers are included. The database is updated monthly.

4 CENTRAL HEATING SYSTEMS WITH DUCTED WARM AIR

Warm air heating systems comprise a central prefabricated unit, which is sized according to the total heating duty and volume of air required by the property. Unit outputs range typically from about 5 kW to 25 kW. Air is distributed by a range of ductwork with a dedicated terminal to each of the rooms.

The heater itself is an indirect gas-fired unit, which incorporates the burner and heat exchanger, an air filter and a centrifugal circulating fan. A flue discharge is required. Airflow can be configured for upward or downward discharge according to requirements. Purpose-provided ventilation is required for the combustion process and a separate supply of return/recirculating air is provided with positive connection to the fan and filter intake.

Ductwork distribution requires specific space being made available in the property. Accordingly these systems work best when purpose-designed into the property from the outset, and when a proper space has been made available for locating the heater. Perimeter air distribution provides better comfort but simple stub ducts from a central location are often installed as the equipment is smaller and the capital costs are lower. Warm air systems have been very popular with local authority developments.

Heater placement is often determined by the ductwork. The single point air supply may offer optimal diffusion but is usually positioned for ease of location, and rooms can experience undesirable temperature gradients. To reduce the spread of odour and humidity, recirculation air is not taken from kitchens, bathrooms and toilets. It is generally more difficult to extend or adapt a warm air system after construction.

Some users disliked the operation of earlier systems because of the thermostatic on/off cycling of the air circulation fan, which led to intermittent heat output. Modern systems are now available with a step-controlled burner and infinitely varying fan-speed to better match the heat supplied with that required. The burner combustion periods also modulate to control the required supply air temperature. The fan will still turn off at low supply temperature at minimum speed (about 60% volume). The latest systems include room-sealed, fan-flued heaters connected to horizontal or vertical terminations. Automatic ignition leads to further fuel saving.

Warm air systems rarely offer individual room temperature control but operate from a single thermostat, so they are not appropriate for properties where highly variable room loads are likely to arise. They are also highly dependent on having air supply volumes properly balanced to the room requirement, which is difficult in practice, so they can suffer from variable temperature distribution within the home.

Having a low thermal capacity, warm air systems are very responsive and are particularly suited to intermittent operation. A properly designed and operated system gives good comfort.

An additional air-to-water heat exchanger is available in many heaters for providing hot water. The water heater can also be used to supply a number of radiators if required. This obviates the need for an additional water heater system and allows water to be provided all year even when the air system is off.

Air quality is a growing issue in the home and warm air systems have the means of addressing some of the factors. The amount of fresh air provided, humidity and the degree of filtration can all be controlled. Improved efficiency can be obtained by using flue heat recovery. This converts a standard warm air heater into a condensing appliance by preheating incoming fresh air with the exhaust flue gases.

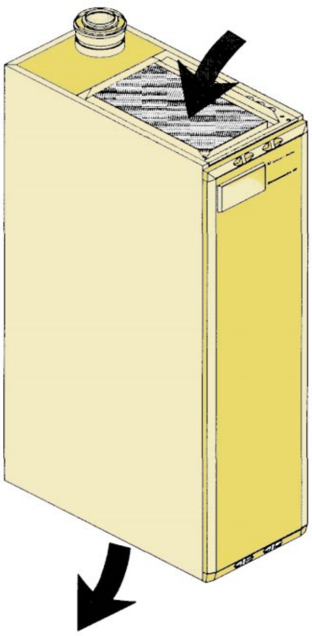


Figure 7 Warm air unit

5 UNDERFLOOR HEATING SYSTEMS

Underfloor heating usually consists of a low-temperature warm water distribution system or electric heating cables set into the floor slab. The system heats the whole floor and emits low-temperature radiant heat throughout the entire space. Normal practice is to design for a mean winter floor-surface operating temperature of 24-25°C; although higher temperatures may be used in circulation spaces or zones of high heat loss, such as areas next to large amounts of glazing.

Underfloor heating systems have many benefits.

- Near to ideal comfort conditions are attained with the feet at a slightly warmer temperature than the head.
- Large spaces, which are difficult to heat evenly from perimeter heat emitters, can be uniformly heated.
- They are unobtrusive. They do not take up any space within the occupied area.
- The low flow temperatures used in underfloor heating makes them ideal for use with condensing boilers. The low return temperatures will raise the efficiency of all boilers, and especially of condensing boilers.

However, the combination of low floor temperature and the high thermal mass means an underfloor system is slow to respond to changes in demand. This makes the system satisfactory for areas of continuous occupation where stable, comfortable conditions can be assured, but unsuitable for areas of highly variable heat gains or losses.

LOW-TEMPERATURE HOT WATER UNDERFLOOR SYSTEMS

The temperature of hot water used for underfloor heating is lower than for radiators with flow and return temperatures of 45°C/35°C often specified. Plastic pipes are laid on the structural floor in a continuous serpentine with flow and return side-by-side to even out temperature differences across the area. Systems employing heat spreader plates are available for use with timber floors, but are less common. The floor screed is then poured over the pipes. This means that the system has a high thermal inertia. The underside of the floor and edges must be well insulated to prevent undue heat loss. The plastics used for piping are generally accepted to provide a long service life of about 50 years.

ELECTRIC UNDERFLOOR SYSTEMS

Electric floor warming comprises a storage heating system that uses the mass of the floor structure to retain heat from an overnight charge and disperse it during the following day.

The cables may be embedded either directly in a concrete screed, or in tubes so that renewal is possible. Electric heating mats are also available that comprise many separate heating circuits so that a broken cable does not compromise the heating system.

The principal difference between a warm water and an electric underfloor heating system is that the electric system necessarily uses the high thermal capacity of the floor to store the charge, whereas the warm water system can continue to be heated

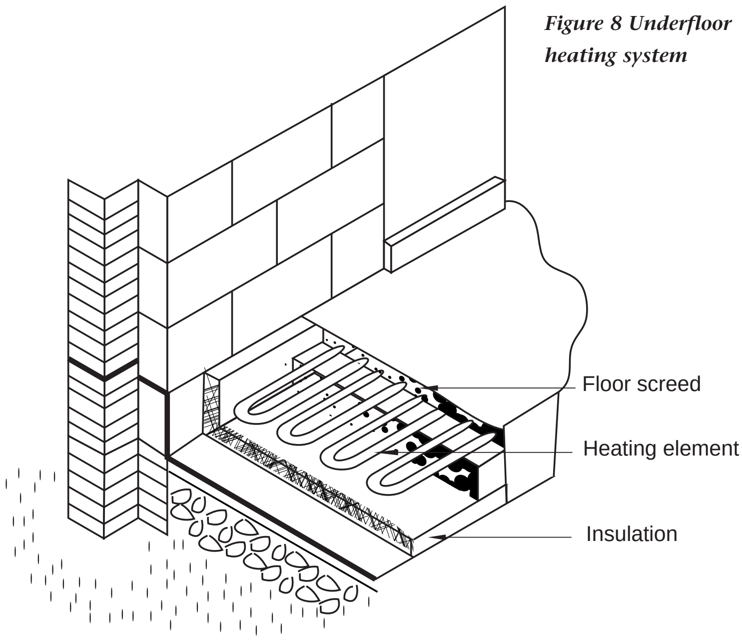


Figure 8 Underfloor heating system

UNDERFLOOR HEATING SYSTEMS

as required. This means that an electric system usually has greater thermal inertia and tends to overheat more readily during occupancy. Heat output also tends to diminish towards the end of the day as the slab temperature cools.

Because of the decay in heat output from electric underfloor systems, it has been common practice to top-up the charge during the day. An additional 10% has been normal practice but higher charges may prove viable. The impact of tariff mix has to be evaluated for each project.

Electric underfloor systems are not recommended as the running costs are relatively high and they are insufficiently responsive.

CONTROL

The combination of low floor temperatures and the high thermal mass of the floor produces a system that is slow to respond to changes in demand. This is compensated, to some extent, by the small temperature differential between the floor surface and room air temperature, which provides a degree of self-regulation and readily stabilises the room temperature.

Careful selection of heating zones is important to ensure that heat output matches building requirements. Their control will have a considerable impact on comfort and energy so systems can be controlled by a local thermostat (globe temperature sensors are better than air temperature sensors).

As underfloor heating systems raise the surface temperature of a significant area of the room the higher mean radiant temperature results in occupants being more comfortable at a lower air temperature than with a convective heating system. This contributes to more economic operation if properly controlled. Furthermore, with condensing boilers, seasonal efficiencies of over 90% can be achieved.

6 ELECTRIC STORAGE HEATING

Electric storage heaters are designed to exploit the cheaper (off-peak) electricity tariffs available overnight. Their principal drawback is that as the stored heat diminishes through the day the heat output tends to reduce in the evening, just at the time it is usually required most. Some electricity supply companies have introduced new tariffs to provide supplementary charging at lower daytime rates.

If the heating provision in a modern home is totally electric then it is recommended that some rooms use direct heating for top-up and control. For example, storage heaters in a living room, dining room and hall will provide the bulk of the house heating with supplementary direct heaters elsewhere. The precise choice of heating appliances will be dependent on property age, type and use – the aim is to limit daytime electricity use to no more than 10% of the total, but this will still increase the energy bill.

ELECTRIC STORAGE HEATERS

A storage heater is constructed from high-density blocks that surround electric heating elements. The blocks are specially made to have a high thermal capacity so that they store a large amount of heat for their size. The heater is encased in an insulated metal case and heating occurs from convection currents passing into the bottom of the casing, through the airways within the storage blocks and out through a grille at the top of the case. The high thermal capacity of

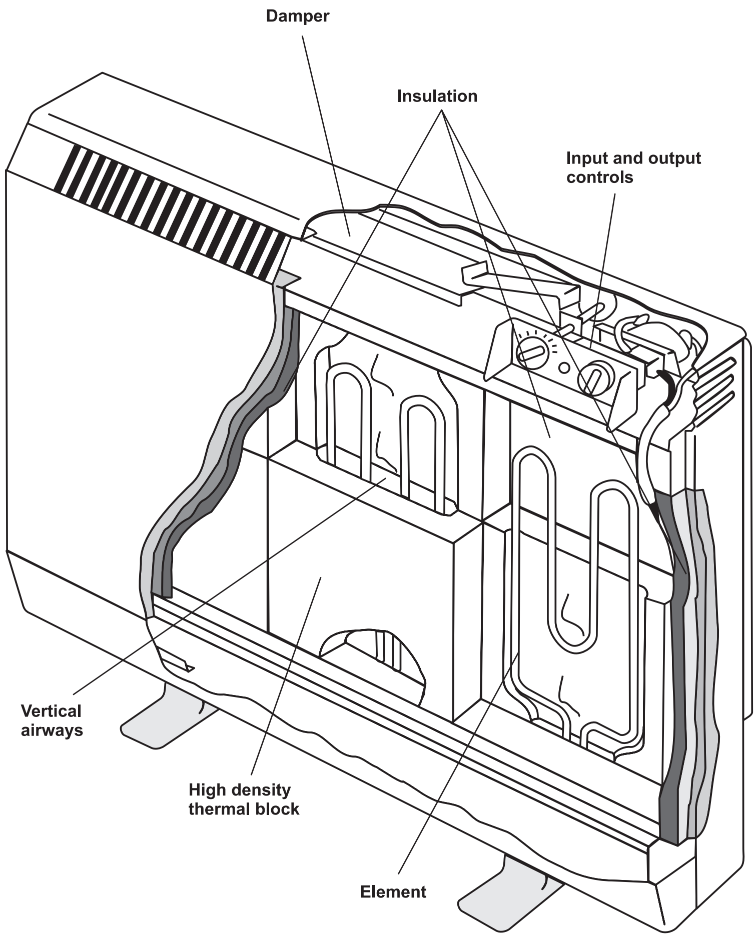


Figure 9 A typical electric storage heater

ELECTRIC STORAGE HEATING

modern storage heaters means that they are smaller than in the past, but still larger than radiators. Storage heaters are heavy and should be fixed to the wall. They are not designed to be portable and require a dedicated electrical circuit.

COMBINATION HEATERS

Combination heaters incorporate a separately controlled direct-acting panel heater with the storage heater, usually on the front face. These provide the flexibility and convenience of providing rapid, supplementary heat output when required. This is useful in the event of a heating shortfall such as in the evening, or if the occasional ‘cold-snap’ occurs and the storage heater has not been charged, such as at the beginning of the heating season.

FAN STORAGE HEATERS

Fan storage heaters are also available, which incorporate a thermostatically controlled fan. These provide better control over heat output, so are more effective, but use some electricity to operate the fan (mostly at day rate). Compared with a normal storage heater, the fan-heater casings are better insulated so heat is given out more slowly, leaving more to be controlled by the thermostat. Fan storage heaters are best suited for boost heating or responding to more variable and larger heat loads.

OPERATION AND CONTROL

The controls of traditional storage heaters provide for charge input and heat output and are set manually. A charge controller prevents overheating of the blocks. This is a cutout thermostat, which switches off the charging circuit when the blocks are sufficiently heated. Heat output is controlled by the direct operation of a damper from a bi-metallic thermostat, which can be preset to the required temperature level by the user. If the room becomes sufficiently warm then the heat output will be reduced by a damper closing behind the discharge grille to restrict the airflow and limit the release of heat to the space.

There are various methods of advanced control for storage heaters, described as automatic charge control or predictive charge control. In principle they vary the overnight charge given to individual storage heaters, or groups of them, so as to provide the right amount of heat for the following day. They use algorithms based on measurement of room temperature or external temperature, or weather forecast information received from an external source. The intention is to provide adequate heating but prevent wasteful overcharging.

Whilst storage heaters offer some thermostatic control, they are fairly unresponsive and need stable room conditions to work well. Furthermore, the warm casing of the heater means that there will always be some standing heat output from the unit. These factors make storage heaters unsuitable for a number of applications:

- daytime occupation that extends into the evening, unless the heaters are supplemented by additional heating during the day
- premises that are unoccupied through the day, unless the heaters are able to be set with reduced output whilst the occupants are out, otherwise the property will be unnecessarily heated and have insufficient heat available when required in the evening
- where heat gains are large and especially when they are intermittent – this could well arise in rooms with a southerly aspect and a reasonable amount of unshaded glazing.

COSTS

Electric storage heating has the advantage of not having to be installed in its entirety from the outset as additional heaters can be added as requirements and finances permit. The capital cost of electric storage heating is low compared with other forms of central heating, but running costs are higher as are the associated CO_2 emissions.

7 ROOM-HEATING APPLIANCES

Homes without central heating systems usually have independent heating appliances that can provide heating and hot water for the home, and they are reviewed in this section. The same appliances are also used for secondary heating in some of those homes.

OPEN FIRES

Most fires are inset into the hearth with a traditional chimney discharge. They are designed to burn a range of solid fuels but will also operate with dried wood or peat. Care must be taken in smokeless zones to ensure that only permitted fuel is used.

Open fires are difficult to control accurately other than by gauging the amount of fuel being burnt and regulating air supply to the grate. It is difficult to ensure even heat distribution from a fire in large rooms with a volume greater than 100 m^3. Convector fires or freestanding fires will increase the amount of convected heat to the larger space.

Back boilers can be fitted to a fire to produce a primary feed to a hot water cylinder and radiators. Typical output is enough to satisfy the heating requirements of a traditional semi-detached house. Some models have underfloor or fan-assisted draught. Proper air supply is vital for open fires and is a regulatory requirement. A permanent fresh-air intake is needed in the room.

The solid-fuel open fire is traditional but suffers the disadvantage of poor response and thermostatic control, which leads to unnecessary overheating and excessive fuel use.

ROOMHEATERS AND STOVES

The fire box in a room heater is enclosed behind a door of heatproof glass. They are more efficient than open fires because less dilution air is drawn into the chimney, improving combustion control and increasing safety. When freestanding and coupled to the chimney by means of a flue pipe, the heaters may be called 'stoves'. Stoves are designed primarily for room heating and should not be confused with cooking appliances. As stoves are not built into the chimney breast, they tend to have larger casings and some have an extra flue-gas pass before discharge. This leads to cleaner combustion, and efficiencies in excess of 70% are possible. There is a wider choice for siting and the opportunity for some attractive designs.

As with open fires these appliances can be dry or have back boilers that provide heating and DHW.

COOKERS

Some cookers have boilers suitable for providing hot water, and some can also heat radiators. Some cookers are insulated to maintain a more even temperature from a smaller heat source. They burn a wide range of solid fuels as well as oil or gas and, because of their high thermal inertia and sustained temperature, have an enviable reputation for cooking quality. However, the constant background warmth can be wasteful in modern properties better suited to intermittent heating. Such appliances remain best suited to properties where the daily lifestyle centres around the kitchen, such as the traditional farmhouse.

All these appliances may be used with different fuels and are predominantly solid fuel. The approving authority for such appliances is HETAS, which awards a 'three tick' symbol of approval indicating quality, performance and efficiency.

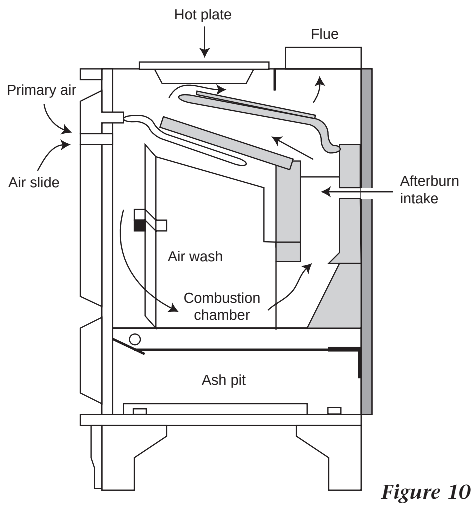
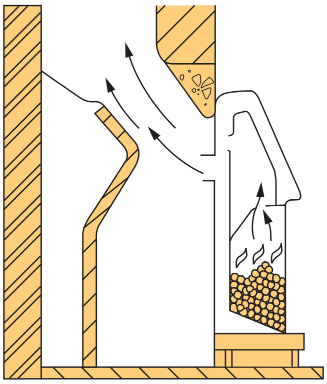


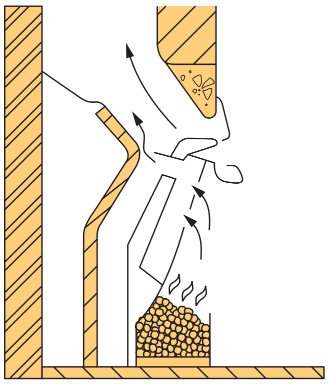
Figure 10 A traditional stove

8 FLAME-EFFECT FIRES

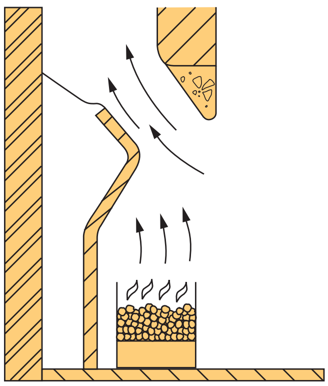
Figure 11 Flame-effect appliances



(a) Radiant convector/live fuel effect



(b) Inset live flame effect



(c) Decorative flame effect

When changing from an open fire or renewing an old gas or electric fire, many householders now choose to install a flame-effect gas fire. These fires realistically simulate the flames and warm glow of burning coal or logs. The appliances are clean and convenient to use and have established widespread appeal.

Three types of fire are available:

- live flame-effect
- inset live flame-effect
- decorative flame-effect.

The differences between these appliances are illustrated in figure 11(a-c), taken from BS 5258.

The amount of enclosure around the fire is crucial to its heating efficiency. The least efficient are those that are purely decorative, built in open baskets or in an open hearth. Decorative (flame-effect) fires of the type illustrated in figure 11(c) are not regarded as heating appliances and there is no requirement to achieve a minimum efficiency. In fact they are described in the European standard as appliances designed to simulate a solid fuel appliance for decorative purposes. Most of the heat is discharged directly up the flue. Inset models can incorporate a blackened ceramic backplate to radiate some of the heat into the room and improve the energy efficiency. Encased fires with restricted flue openings are more efficient and those that incorporate glass fronts are better.

Efficiency can be improved further by incorporating a secondary heat exchanger into convector fires, which allows room air to be warmed and returned to the room through a grille at the top of the fire casing.

The most efficient fires are totally encased behind heat-resistant glass, which not only adds to safety but ensures that both radiative and convective heat transfer occurs most efficiently.

Room-sealed fires, with balanced flues, need no other form of ventilation, but most fires will take their combustion air from the room. For safety reasons a permanent fresh air grille must be fitted for fires with inputs greater than 7 kW and all decorative fires.

For convenience, most fires have remote piezo ignition but all enclosed fires require this facility. Flame failure devices must be fitted to prevent the emission of unburnt gas should the gas flame be extinguished. Concerns in recent years over carbon monoxide poisoning due to inadequate ventilation or restricted flues have led to the fitting of oxygen-depletion sensors on newer appliances. This detects the decrease in oxygen due to increase in carbon monoxide and switches off the flame to prevent further production of the lethal gas. In accordance with BS 5871[7] fires should be CE marked and must be installed by a Corgi-registered installer.

A further important consideration in the choice of fire is to assess the available flue. Four types are generally available:

- open flue – this may be an existing chimney (Class 1 flue)
- pre-cast concrete flue – found in newer homes, it may be a set within the wall (Class 2 flue)
- prefabricated flue – a twin-skinned stainless steel flue attached to the wall and discharging at high level (Class 2 flue if less than 152 mm)
- no chimney exists – in which case a fan-assisted or balanced flue will need to be installed with the appliance.

Fire type	Typical efficiency
Gas fire, open flue, pre-1980	50%
Gas fire, open flue, 1980 or later	60%
Gas fire or wall heater, balanced flue	70%
Room heater, fan-assisted flue	75%
Condensing gas fire	85%
Flush-fitting live fuel-effect gas fire, sealed to chimney	50%
Flush-fitting live fuel-effect gas fire, fan-assisted flue	45%
Decorative fuel-effect gas fire, open to chimney	20%

Table 3 Comparison of gas-fire efficiencies

9 WATER-HEATING APPLIANCES

Domestic hot water (DHW) may be obtained from either of two ways:

- storage systems – a central storage cylinder stores the hot water in readiness for use
- instantaneous systems – combi boilers or direct-acting water heaters generate the hot water locally on demand.

These hot water systems described below, have different characteristics.

HOT WATER CYLINDERS

Boiler systems will often employ a vented indirect storage hot water cylinder. For small dwellings with a single bathroom this is typically of 120 litres capacity. Larger dwellings with more than one bathroom will require a larger cylinder capacity. High-performance cylinders are now available containing a larger heating coil, which reduces the time taken for the water to be heated, and will reduce boiler cycling. This helps to increase the system efficiency, especially with older boilers. Indirect hot water cylinders should perform at least as well as required by BS 1566[8]. Cylinders with bigger heat exchangers and thicker insulation are available, and the British Standard should be regarded as the minimum. Factory-applied foam insulation is preferable and insulation jackets should only be used to improve the insulation of existing cylinders. Some cylinders are referred to as 'medium duty' and are inferior to the requirements of BS 1566 as they are usually poorly insulated and have too small a heat exchanger. Accordingly, they should not be used.

The water in the cylinder may be heated by electric immersion heater(s). A typical domestic immersion heater would have a power rating of 3 kW. Some larger cylinders may have two immersion heaters. One is at low level to maximise the store of heat from cheap-rate electricity (eg overnight) and ensure a minimal top to bottom temperature gradient. A high-level heater provides small quantities of top-up hot water as required if the stored hot water is depleted.

Unvented cylinders have become increasingly popular in recent years. These operate at mains pressure with either an internal expansion facility or a dedicated external expansion vessel. They have the advantage of eliminating the need for a cold water tank in the loft so reducing material and installation costs. They also minimise the risk of freezing and improve blending at showers and taps because the hot water is supplied at mains pressure. Different British Standards and installation safety requirements apply.

COMBI BOILERS

Combi boilers can be fired by gas or oil and provide both space heating and DHW. The most common type is the instantaneous combi, which heats water on demand without a store. One of the benefits of this system is that it is simpler to install than a conventional system, as an indirect hot water storage cylinder is not required. A full description of the types and operation of combi boilers, and comparison with hot water storage systems, is given in GPG 284[1].

INSTANTANEOUS HEATERS

The gas-fired instantaneous water heater was once common but has now largely been superseded by the combi boiler. An instantaneous domestic water heater is now more likely to be electric. They are good for remote positions, which would otherwise require long pipe runs. With a single outlet, the water flow is controlled from a tap on the inlet. Multi-point heaters are instantaneous heaters, which serve more than one outlet, and their water flow is controlled by taps at each outlet.

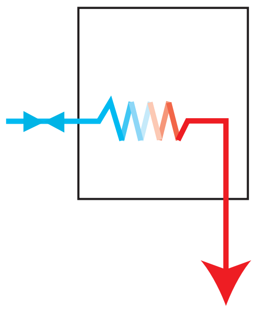


Figure 12 Instantaneous water heater

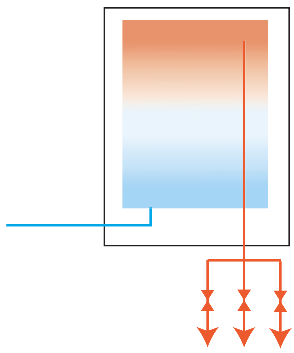


Figure 13 Multi-point water heater

WATER-HEATING APPLIANCES

SHOWERS

A shower normally uses less water and has become more popular than a bath, with ownership now in about 35% of households. There are three types of domestic shower.

Mixer showers are fed with hot and cold water, either from a low-pressure supply or the mains (if hot water at mains pressure is available). Temperature control can be manual or thermostatic and flow rates depend on pressure. The hot water may come from a cylinder, which also supplies other outlets, and is heated by the central heating boiler. Some manufacturers produce ‘pressure balanced’ showers specifically for combis and care should be taken when matching the appliances.

Power showers are mixer showers with a pumped supply to increase the water flow rate, typically 12-25 litres per minute. This is far more than can be heated instantaneously and power showers will use more hot water than a bath after a short while. The pump motors are expensive and noisy.

A recent development is the hydrodynamic or ‘venturi’ shower that uses the pressure in the cold water system to entrain the hot water, which eliminates the need for an electric pump.

Electric showers are fed with cold water only, which is heated instantaneously as the water flows. Domestic power ratings are limited to a maximum of about 10 kW. Flow rates are relatively low at about 4-8 litres per minute, depending upon power rating and required temperature rise. This is often exacerbated by low mains pressure at times of peak use and it is sometimes difficult to get good performance from them.

Showers typically use about 300 kWh/yr/household. Running costs and associated CO_2 emissions of electric showers are much higher than mixer showers using water heated by gas.

WATER QUALITY

Nearly half of England and Wales is supplied with hard water. As the water is heated the carbonate salts in the water come out of solution and are deposited on surrounding surfaces, favouring the higher temperatures. Heating elements become scaled, resulting in reduced heat output and a greater tendency to overheat and burn out. Accordingly, some electric shower manufacturers design their showers for easy removal and replacement of the heating element. Scaling of heat exchangers reduces heat transfer rates and is wasteful of energy. Problems of scaling due to water hardness can only be avoided by the installation of water-softening equipment.

10 MICRO CHP, HEAT PUMPS AND SOLAR WATER HEATING

MICRO CHP

Combined heat and power (CHP) is now an established technology in large buildings offering significant energy efficiency and environmental benefits (see section 11). However, until recently, it was not possible to obtain small CHP systems at sizes less than about 5 kWe – too large for a single house.

Micro CHP comprises an engine driving an electrical generator that offers individual homes their own small electrical generating capacity, also supplying heat and hot water. Micro CHP systems provide enough heat for domestic heating and hot water, and are rated at about 1 kWe. Products could be commercially available by 2003.

Some of the electricity used in the home is generated from the micro CHP unit rather than a power station, and heat from the generating equipment that would otherwise be wasted can be used in the home. Supplementary electrical power will be required from the grid at times of peak use, and the CHP will export power when the demand of the dwelling is less than that generated by the CHP.

Although the technology is yet to be established, micro CHP systems have the potential to make a saving in CO_2 emissions from the home. Manufacturers' claims are that CHP engines will cost around £600 more than conventional domestic boilers, and can reduce annual domestic electricity bills by £150 to £300.

HEAT PUMPS

What is a heat pump?

Heat flows naturally from high temperature to low temperature. Heat pumps are able to reverse this simple principle and take heat from a low temperature 'source' (such as air, water or the ground) and discharge it at a higher temperature in a building.

A heat pump is the same as a refrigeration system. There are four essential components and a circulating refrigerant provides the heat transfer. A compressor pressurises the refrigerant gas and pumps it to a condenser where it cools and releases its heat to either a water circuit or air to heat a building. The condensed refrigerant, still at high pressure, then passes through an expansion valve where the rapid expansion induces cooling. The drop in temperature liquifies the refrigerant, which passes on to the evaporator. Here the cold liquid evaporates as it picks up heat from the surroundings. A typical evaporating temperature is –2ºC so it can readily collect heat, even in winter.

The efficiency of a heat pump is measured by its coefficient of performance (COP). A typical value would be about 3.0, which means that for every 1 kWh of electricity used to drive the compressor, 2 kWh of (free) heat is collected from the evaporator and 3 kWh of useful heat is delivered to the building.

The source of heat can be air, water or the ground. A high source temperature leads to a higher COP, so air source heat pumps are the least efficient with typical seasonal COPs of 2.0 - 2.5, whereas well-controlled ground source heat pumps are the most efficient, with COPs of over 3.0 being achieved.

Air source heat pumps suffer from icing of the evaporator coil in winter and the energy required to melt this further reduces the COP. Air distribution fans on both evaporator and condenser coils add to the system energy overhead. Water coils are relatively trouble free but suitable locations are not always ready to hand. Ground source coils suffered from icing in their formative development but modern systems have cured this problem and the system is currently finding a revival in the UK. They also require a large space for burial of the evaporator coil so are usually only suitable for new build.
A more general problem with domestic heat pumps is that the electricity required can be greater than 5 kW and may require a three-phase supply, which is not generally available in UK homes.

The market

Heat pumps are well established in the commercial and industrial sectors. Since 1992, approximately 3000 heat pumps have been installed in single-family homes in the UK, plus a very small number

MICRO CHP, HEAT PUMPS AND SOLAR WATER HEATING

in multi-family homes. Approximately 40% of the installations are believed to be air-water heat pumps for domestic swimming pools. With the growth of low-energy properties and a desire to improve the quality of fresh air provision to homes, there has been some growth in the use of portable air conditioners in homes due to active promotion. There is greater concern at the potential growth of reverse-cycle heat pumps in homes to provide summer cooling, which will counteract the energy and environmental benefits otherwise obtained.

Heat pumps have a much higher capital cost than alternative heating systems.

Monitoring of a ground source heat pump system is reported in General Information Report 72[9], which concludes that compared with a gas condensing boiler, the heat pump was more expensive to run but had slightly lower CO_2 emissions. The same report urges caution in evaluating the true environmental effects of electric heat pumps, as the CO_2 emissions are dependent not only on the total energy used but also on the demand profile and the actual emissions from the operational power stations.

SOLAR WATER HEATING

Active solar water heating systems are established as a reliable and accessible way to actively use renewable solar energy in homes, with over 42 000 currently in use throughout the UK.[10]

A common size of solar panel for domestic use is about 3 - 4 m^2. This will deliver about 1000 kWh per year, which will heat just over half the annual hot water demand of a typical home. Most of this occurs in summer so it is necessary to supplement solar heating with a conventional boiler or other system.

A typical solar water heating system comprises collectors and a water storage cylinder with connecting pipework, as shown in figure 14. Some systems use thermosyphons (the natural buoyancy of the heated water) to circulate the heating water, but most UK systems need a pump because of low temperature difference.

Collectors

There are four main types of solar collector that can be used in active solar heating systems. These are:

- evacuated tubes
- selective surfaced flat plate
- non-selective surfaced flat plate
- unglazed plastic collectors.

All types of collector can be used for DHW systems with the exception of the less expensive and unglazed plastic collector, which is used exclusively for outdoor swimming pools where lower water temperatures are required.

Collectors need to be mounted as near perpendicular to the incident sun as possible. Mounting on a pitched roof is typical but collectors can also be sited on flat roofs, walls, the ground or post-mounted with a solar tracker.

Flat-plate collectors comprise metal surfaces boxed behind glass or plastic in which water flows through pipes brazed onto the plates. The collector surfaces can be selectively coated to improve their heat-collection efficiency. They are the most common form of solar collector in the UK.

Evacuated tube collectors are constructed as a tube-in-tube. Sunlight enters the outer tube and strikes the inner absorber tube, heating the heat-transfer fluid. The outer tube is highly insulated, using a vacuum inside the glass. The collectors perform well in both diffuse and direct sunlight and are very responsive to weather changes as alcohol can be used as the heat transfer fluid rather than water. Collector panels generally comprise a number of tubes connected to a common manifold. These collectors generally cost more than the equivalent flat panel, balanced by their better performance.

MICRO CHP, HEAT PUMPS AND SOLAR WATER HEATING

In the UK climate, evacuated tube collectors are generally more efficient than selective surface flat-plate panels (per unit absorber area), which in turn are more efficient than flat-plate panels without a selective surface.

Operation

The hot liquid from the collector(s) is normally pumped to a well-insulated storage cylinder. The cylinder is usually tall and thin to maximise stratification and solar heat is indirectly exchanged to the DHW via a coil allowing use of special anti-freeze in the collector.

Where the primary (collector) circuit requires a pump, a differential temperature controller is usually required. In its simplest form, a comparison between (high) collector temperature and (low) store temperature is made to enable solar heat to be given to the store without needless electricity use or wasteful disposal of stored heat. Primary pumps can be driven by photovoltaic (PV) power.

Most systems cannot be simply shut off when it gets too hot, so a large enough store is required to absorb the summer peak gains without overheating or boiling within the secondary storage tank. A typical cylinder capacity is about 40 litres per m^2 of collector.

Systems do not respond well to a high demand for hot water early in the morning but, later in the morning, water drawn off ensures that there is more cool water ready to receive solar heat at the peak of the day. Well-insulated cylinders will allow hot water to be held-over until the following day.

The relatively high capital costs of solar hot water systems means long payback periods with only modest cost savings for all fuels. Consequently they are not among the most cost-effective energy-saving measures. For a range of hot water energy usage of 1000 - 3000 kWh per year, annual savings of 0.1 to 0.3 tonnes of carbon per dwelling can be achieved where electricity is the displaced fuel.

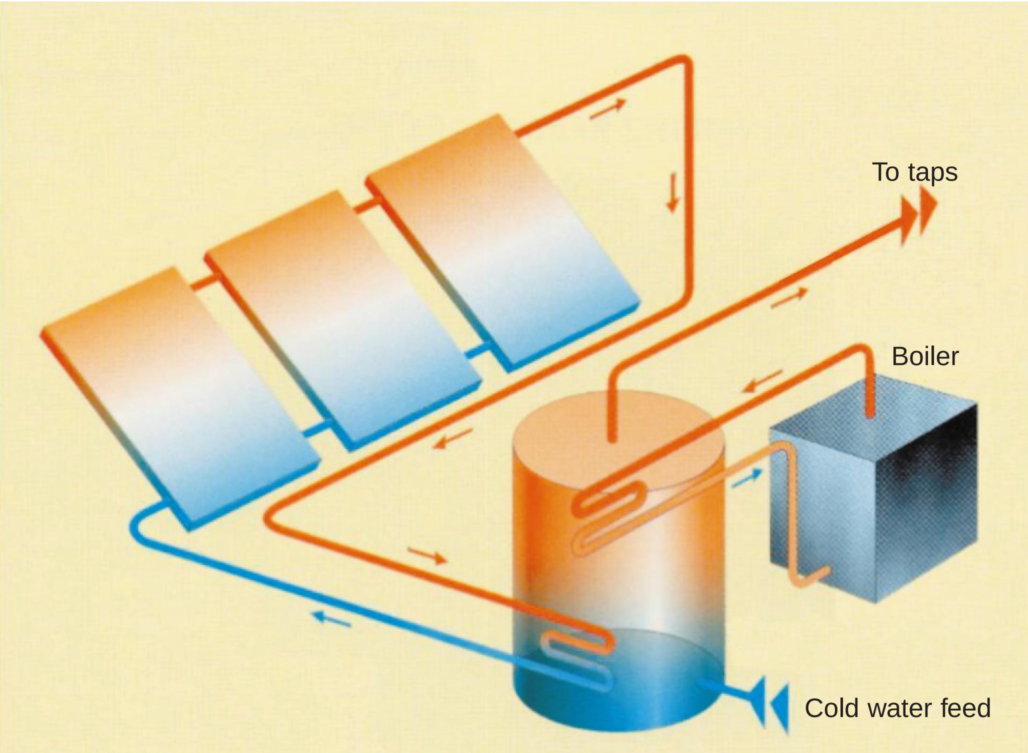


Figure 14 A typical active solar heating system

11 COMMUNITY HEATING AND CHP

COMMUNITY HEATING

Community heating (CH) with CHP offers a sustainable solution for housing and non-domestic buildings alike, enabling buildings whose individual heating profiles could not justify it to make use of CHP. They also offer affordable warmth by delivery of much lower running costs, and there are also opportunities for lower-cost electricity.

CH is where a group of separate buildings and/or dwellings are supplied with heat from a single source. Heat is usually distributed to users as hot water in well-insulated, underground pipes.

CH is not new, having been established in the UK for over 30 years. Something like 250 000 homes are connected to CH schemes in the UK, yet this represents less than 2% of homes. Other countries including, for example, climatically similar Denmark and the Netherlands have considerably more schemes. Schemes range in size from those serving a single tower block to networks that are city-wide. Such schemes can offer substantial carbon emission reductions due to economy of scale in a large central plant, and because they can be serviced by highly efficient CHP plant, or by zero-carbon Energy from Waste plant.

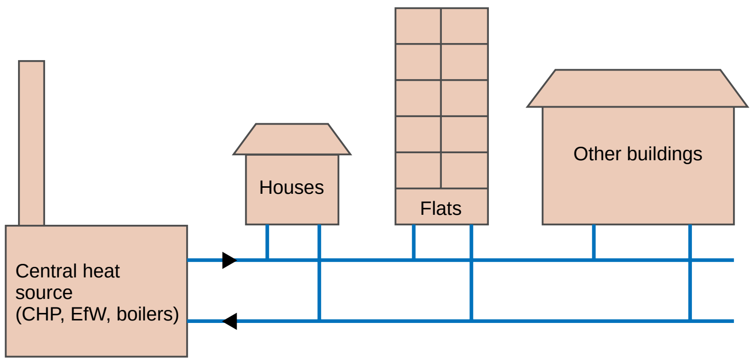


Figure 15 Schematic diagram of community heating

Householder benefits	Landlord benefits
Affordable warmth	Lower maintenance costs
Controllability	Lower management costs
Abundant hot water at high pressure	Fewer voids
Metered heat (fair billing)	Lower life cycle cost
Opportunities for low-cost electricity (CHP)	No risk from faulty gas boilers

Table 4 Benefits of community heating

Early schemes suffered from poor standards of installation and were unreliable but modern systems have resolved these problems, particularly with state-of-the-art pipework, surveillance and controls. CH systems also have to use the existing infrastructure and require relatively high-density housing to be most efficient.

Energy linking

Where there is no CH scheme, 'energy linking' may provide a means of connecting boilers (or other heat sources) from adjacent sites into a common distribution system. This utilises plant more fully as different buildings have their own characteristic patterns of energy use; it improves plant efficiency and helps to avoid duplication – thereby saving money and space. Most importantly, the strategy allows for the gradual growth of a developing CH system. A good example of this is the development in Lerwick, described opposite.

Heat metering

The charge made for heat is a crucial aspect of CH systems. Flat-rate service charges are simple to manage but do not relate to individual customer usage so, therefore, provide no incentive to avoid unnecessary waste.

Heat metering is now a well-developed technology and should be seriously considered for all CH schemes as it:

- ensures equitable billing between customers
- encourages more careful use of energy
- can allow prepayment, and therefore reduces the cost of administering bad debts.

By using central plant, CH schemes operate at high efficiency and benefit from competitive fuel purchasing. CH networks can utilise any fuels, while gas-fired CHP is a very fuel-efficient option. Energy from Waste, biofuel, heat pumps and even solar can all potentially be integrated into a network.

COMMUNITY HEATING AND CHP

COMMUNITY HEATING IN LERWICK

A new 8 MW waste incinerator in Lerwick, on the remote island of Shetland, is supplemented by an 8 MW oil boiler installation to provide the first phase of a CH scheme. Unlike the rest of the UK where CH schemes tend to be municipal housing, this scheme is notable as it is driven by private householders – 75% of the population are signed up to connect when heat becomes available. Heat sources from the local power station, industry and commerce are being explored as 'energy linking' has the potential to provide heating throughout the whole community of 8000 people.

CHP MEETS NEEDS OF SOCIAL HOUSING PROVIDER

St Pancras Housing (SPH) opted for a 54 kWe gas engine CHP plant when it upgraded the primary heat source for 95 of its flats and an elderly persons' community centre, 10 commercial units and SPH's London head office.

It was decided that a single CH plant should be provided to supply both St Richard's House and the adjacent Hillwood House, so the heating systems in each block were linked via a pair of heat mains. Furthermore, SPH decided to sell the electricity generated directly to its tenants as a means of further reducing its tenants' energy cost. The CHP plant, lateral electrical cabling and metering system were purchased outright. SPH received a contribution of £45 000 (equivalent to 17% of the total scheme cost) from the Energy Saving Trust's (EST's) CHP in Residential Buildings grant scheme.

Further information on CH is given in GPG 240[11] and GPG 234[12].

COMBINED HEAT AND POWER

CHP is the local generation of electricity and use of the waste heat produced to contribute to the heat required in the buildings.

Power stations reject the heat produced from electrical generation, but CHP systems use it to satisfy a thermal load. CHP systems are therefore much less wasteful than the separate boiler and electrical supply plant that they displace. The higher energy efficiency means that the running cost of the heat and electricity they produce is cheaper than that from separate energy suppliers. Most CH schemes operate at relatively low temperatures and gas-engine CHP is usually the most cost-effective option.

Electricity production is the most valuable output of CHP but the plant requires a base heat load if generation is to continue. Most schemes are typically designed to meet the summer hot water load and additional heating requirements are met by supplementary boilers. The resulting high-efficiency production of both electricity and heat, particularly from gas, have clear environmental benefits.

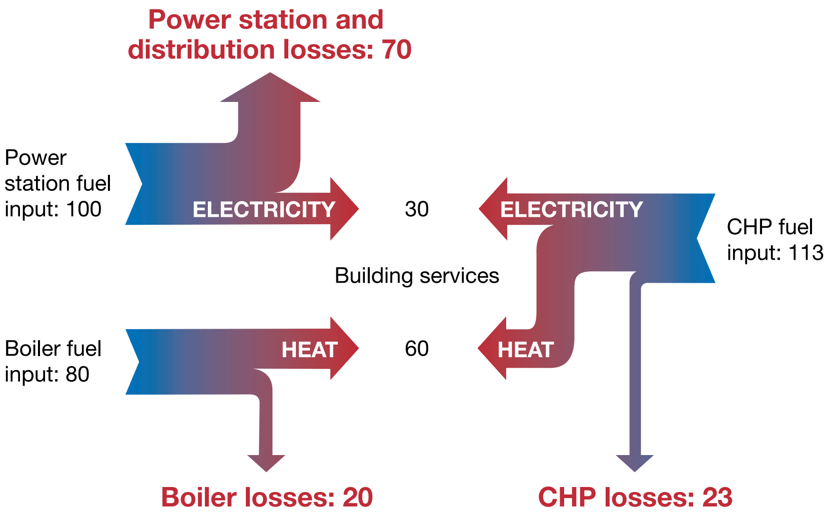


Figure 16 Energy flow diagram. CHP uses the heat that is usually wasted when electricity is generated from fossil fuels. Existing CH systems provide a ready-made heat load for CHP

COMMUNITY HEATING AND CHP

By the end of year 2000 the total installed capacity of CHP in the UK was 4700 MWe spread throughout approximately 1400 sites and contributing about 7% of the UK electricity consumption; the UK target for 2010 is an installed capacity of 10 000 MWe. This represents one-third of the UK's international commitment to meeting carbon savings, so CHP is an important contributor.

The installed capacity of UK central heating schemes with CHP is only about 214 MWe. The vast majority, around 200 MWe, is installed in large-scale multi-use CH schemes such as those in London (Citigen), Nottingham, Sheffield, Slough and Southampton. Despite the significant potential, only 14 MWe of CHP is installed in small-scale domestic, or residential, heating schemes. Most of these schemes export the generated electricity to the grid. The relatively low export prices paid for the comparatively small amount of electricity generated from this CHP has significantly restricted the number of installations. A few schemes, such as the St. Pancras Housing schemes, have pioneered the direct sale of electricity to tenants to increase scheme revenue and economic viability whilst reducing the cost to the user (see New Practice Profile 112[13]).

Grants

A recent scheme at Southwyck House in the London Borough of Lambeth incorporated a 210 kWe CHP unit as part of an existing CH network serving 173 dwellings in five tower blocks. Not only does it represent a major project but it was also supported by grants from the CHP Programme run by the EST.

The EST Residential CHP Programme, funded jointly by the Transco Affordable Warmth programme and the Government, has provided development grants and capital funding for residential schemes. This is now linked to the Energy Suppliers' Energy Efficiency Commitment, which places the requirement on energy suppliers to improve energy efficiency for domestic customers.

A comprehensive guide to CH and CHP is given in GPG 234[11]. Small-scale CHP for buildings is reviewed in GPG 176[14] and the environmental aspects of CHP usage are considered in GPG 115[15] and 116[16].

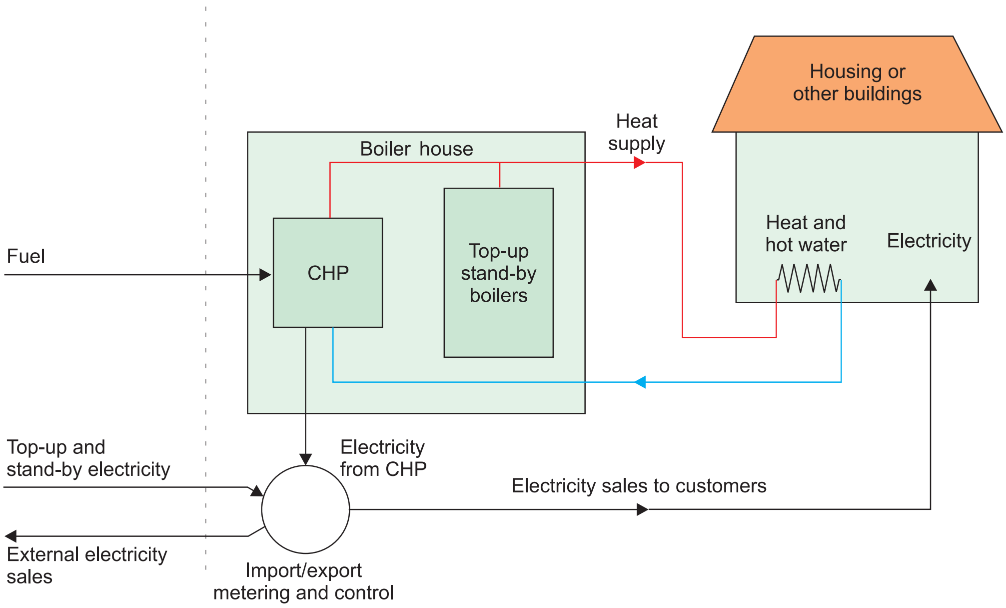


Figure 17 In practice, heat and electricity from CHP systems are supplemented by top-up boilers and by connection to the electricity distribution network. This ensures reliability of supply and provides opportunities for electricity sales to other customers

12 OTHER FACTORS

BUILDING ENVELOPE

The most important start to saving energy in the home is to reduce the need for heat by insulating the fabric of the building and protecting against unwanted entry of cold outside air.

The steady-state heat loss of the building fabric is directly proportional to its thermal transmittance (or 'U' value) – the lower the value the better. The building heat loss, and energy requirement, can be reduced by the use of different materials, such as replacing dense blocks with lightweight blocks, or more commonly by adding a further insulating material.

Guidance on energy efficiency building measures is provided in GPG 171[17] and GPG 155[18].

BUILDING REGULATIONS

Part L of the Building Regulations for England and Wales (Part J and Part F in the corresponding legislation for Scotland and Northern Ireland, respectively) requires that 'reasonable provision shall be made for the conservation of fuel and power' in buildings. It specifically requires limiting heat loss through the fabric of the building, from hot water pipes and hot air ducts used for space heating, and from hot water storage vessels. Other requirements of particular relevance to heating are that space and water heating systems should be energy efficient and that building occupiers should be provided with sufficient information to allow them to operate their heating and hot water services efficiently. Part L was revised during 2001, with new requirements in force from April 2002 (Part L1 deals with dwellings, Part L2 with other buildings).

Under Part L, heating becomes a 'controlled service' from April 2002, and for the first time the provisions apply to 'material alterations' carried out to existing heating systems. So the Regulations must be taken into account not just in new buildings but also when renewing systems in existing buildings.

Approved Document L1[4] gives detailed practical guidance showing how the requirements may be met. For dwellings, three alternative ways of demonstrating compliance with the insulation requirements are allowed.

Elemental method

The requirements (see table 5) will be met if the U-values of the construction elements meet specified values. This method sets minimum efficiencies for boilers and cannot be used with direct electric heating (including storage heaters). The principal limiting design values are shown in table 6.

Target U-value method

This method allows the average U-value of a property to be calculated and compared with the average U-value for an identical property built using the 'Elemental' U-values and boiler efficiencies. So long as the net effect is no worse than with the Elemental U-values the design will comply. This method allows the insulation levels in different parts of the building to be adjusted and 'traded-off' against higher boiler efficiencies.

Carbon Index method

This method also allows insulation levels and heating systems to be adjusted so long as a Carbon Index of at least 8.0 is achieved. The Carbon Index is affected by choice of fuel and the heating system efficiency, and represents the carbon dioxide emissions per unit area measured on a scale from

Building component	U-value
Wall	0.35
Roof (with loft)	0.16
Floor	0.25
Window	2.0/2.20

Table 6 'Elemental' U-values for dwellings required by the Building Regulations (LI)

Table 5 Requirements of the Building Regulations for Dwellings

Topic	Requirement
Fabric U-value	Energy compliance: ■ elemental assessment ***or*** ■ target U-value assessment ***or*** ■ Carbon index Thermal bridges around openings detailed
Ventilation	Methods to limit infiltration provided
Heating system	Control requirements specified: ■ zone control ***and*** ■ timing control ***and*** ■ boiler interlocks
Hot water service	Control requirements specified: ■ thermostat required ***and*** ■ timer control
Vessels/pipes and ducts	Minimum insulation stipulated

OTHER FACTORS

0.0 to 10.0. It is calculated using the Standard Assessment Procedure (SAP) – see panel on page 4.

Apart from boiler efficiency, the most relevant requirements for heating system providers are those concerning controls, commissioning, and provision of operating and maintenance instructions. The requirement for control of heating systems in dwellings may be met by zone controls, timing controls and boiler interlock. The requirement for commissioning is introduced for the first time in the year 2000 revision and applies to both new and existing buildings. Responsibility for commissioning rests with the person carrying out the work and includes the recording of system settings and performance test results. A certificate must be made available to the client and the building control body; the certificate issued under the Benchmark Code of Practice for the Installation, Commissioning and Servicing of Central heating systems is considered suitable for this purpose.

REFERENCES

[1] ***Energy Efficiency Best Practice programme.*** Good Practice Guide 284. 'Domestic central heating and hot water: systems with gas and oil-fired boilers'. EEBPp, London, 2000

[2] ***Building Research Establishment.*** BRE Report BR 35. 'BREDEM-12'. BRE, Garston, 1996

[3] The Government's Standard Assessment Procedure for Energy Rating of Dwellings. 2001 edition

[4] The Building Regulations 2000, Conservation of Fuel and Power, Approved Document L1, The Stationery Office, London

[5] ***Department of Trade and Industry.*** Digest of United Kingdom Energy Statistics 2001. DTI, London, 2001

[6] Domestic Energy Fact File 1998, BRE Report 354

[7] BS 5871:1991 Specification for installation of gas fires, convector heaters, fire/back boilers and decorative fuel effect gas appliances

[8] BS 1566:1984 Copper indirect cylinders for domestic purposes

[9] ***Energy Efficiency Best Practice programme.*** General Information Report 72. 'Heat pumps in the UK – a monitoring report'. EEBPp, London, 2000

[10] ***Energy Efficiency Best Practice programme.*** General Information Report 88. 'Solar hot water systems in new housing – a monitoring report' EEBPp, London, 2001

[11] ***Energy Efficiency Best Practice programme.*** Good Practice Guide 240. 'Community heating – a guide for housing professionals'. EEBPp, London, 1999

[12] ***Energy Efficiency Best Practice programme.*** Good Practice Guide 234. 'Guide to community heating and CHP'. EEBPp, London, 1998

[13] ***Energy Efficiency Best Practice programme.*** New Practice Profile 112. 'Opportunities for electricity sales to tenants from residential CHP schemes'. EEBPp, London, 1999

[14] ***Energy Efficiency Best Practice programme.*** Good Practice Guide 176. 'Small-scale combined heat and power for buildings'. EEBPp, London, 1999

[15] ***Energy Efficiency Best Practice programme.*** Good Practice Guide 115. 'An environmental guide to small-scale combined heat and power'. EEBPp, London, 1998

[16] ***Energy Efficiency Best Practice programme.*** Good Practice Guide 116. 'Environmental aspects of large-scale combined heat and power'. EEBPp, London, 1998

[17] ***Energy Efficiency Best Practice programme.*** Good Practice Guide 171. 'Energy efficiency primer'. EEBPp, London, 1997

[18] ***Energy Efficiency Best Practice programme.*** Good Practice Guide 155. 'Energy-efficient refurbishment of existing housing'. EEBPp, London, 2001

FURTHER INFORMATION

ENERGY SAVINGS ADVICE FOR HOUSEHOLDERS

For advice and details of energy-saving offers, householders should contact the Energy Efficiency Hotline on 0845 727 7200.

A website with individual boiler efficiency results is available on **www.boilers.org.uk**.

FURTHER READING

BRE

- BR 35. BREDEM-12

ENERGY EFFICIENCY BEST PRACTICE PROGRAMME DOCUMENTS

The following Best Practice programme publications are available from the BRECSU Enquiries Bureau. Contact details are given on the back cover.

Energy Consumption Guides

3 A tenant's guide to affordable heating
4 A homeowner's guide to affordable heating

General Information Leaflet

31 Building Research Establishment Domestic Energy Model (BREDEM)
59 Central Heating System Specifications (CHeSS)

General Information Report

32 Review and development of energy efficient refurbishment standards for housing associations
72 Heat pumps in the UK – a monitoring report
88 Solar hot water systems in new housing – a monitoring report

Good Practice Case Studies

10 Energy efficiency in new housing. Llanerchydol Park, Welshpool. Frank Galliers Ltd
68 Energy efficient refurbishment of high-rise housing. Stannington Estate, Sheffield
82 Consumer connection to community heating in Sheffield
87 Modern domestic coal-fired boilers
108 Energy efficiency in housing. Low-energy sheltered housing in Scotland
239 Energy efficient refurbishment of housing. Barbican district of Plymouth
257 Northern Ireland's energy saver house
306 Application of energy efficient pattern book housing
313 Community heating in Nottingham: domestic refurbishment
315 Energy efficient refurbishment of solid walled houses
316 Energy efficient refurbishment of solid walled flats
318 Energy efficient refurbishment of cavity walled flats

Good Practice Guides

115 An environmental guide to small-scale combined heat and power
116 Environmental aspects of large-scale combined heat and power
132 Heating controls in small commercial and multi-residential buildings
155 Energy-efficient refurbishment of existing housing
171 Energy efficiency primer
173 Energy efficient house design – exploiting solar energy
176 Small-scale combined heat and power for buildings
234 Guide to community heating and CHP
240 Community heating – a guide for housing professionals
284 Domestic central heating and hot water: systems with gas and oil-fired boilers
302 Controls for domestic central heating and hot water

New Practice Profile

112 Opportunities for electricity sales to tenants from residential CHP schemes

This document is based on material drafted by Delta Energy under contract to BRECSU for the Energy Efficiency Best Practice programme.

The Government's Energy Efficiency Best Practice programme provides impartial, authoritative information on energy efficiency techniques and technologies in industry and buildings. This information is disseminated through publications, videos and software, together with seminars, workshops and other events. Publications within the Best Practice programme are shown opposite.

Visit the website at **www.housingenergy.org.uk** or **www.energy-efficiency.gov.uk**

Call the Environment and Energy Helpline on **0800 585794**

Energy Consumption Guides: compare energy use in specific processes, operations, plant and building types.

Good Practice: promotes proven energy-efficient techniques through Guides and Case Studies.

New Practice: monitors first commercial applications of new energy efficiency measures.

Future Practice: reports on joint R&D ventures into new energy efficiency measures.

General Information: describes concepts and approaches yet to be fully established as good practice.

Fuel Efficiency Booklets: give detailed information on specific technologies and techniques.

Introduction to Energy Efficiency: helps new energy managers understand the use and costs of heating, lighting, etc.